# Description and Specifications of the MI BPM Transitionboard

M. Wendt

October 10, 2005

**Abstract**

This document briefly specifies and describes the so-called *Transitionboard* of the MI BPM Upgrade project.

## Introduction

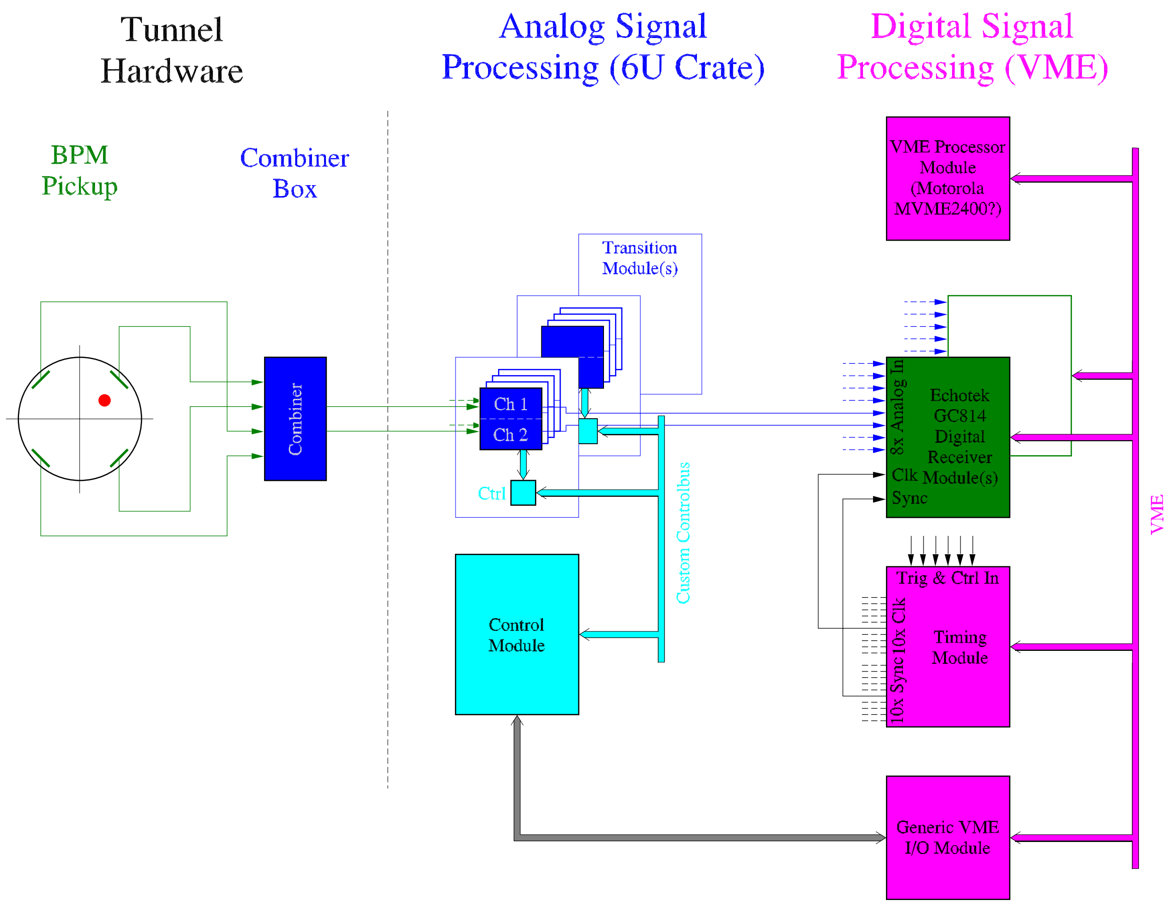


Figure 1: Overview of the MI BPM hardware.

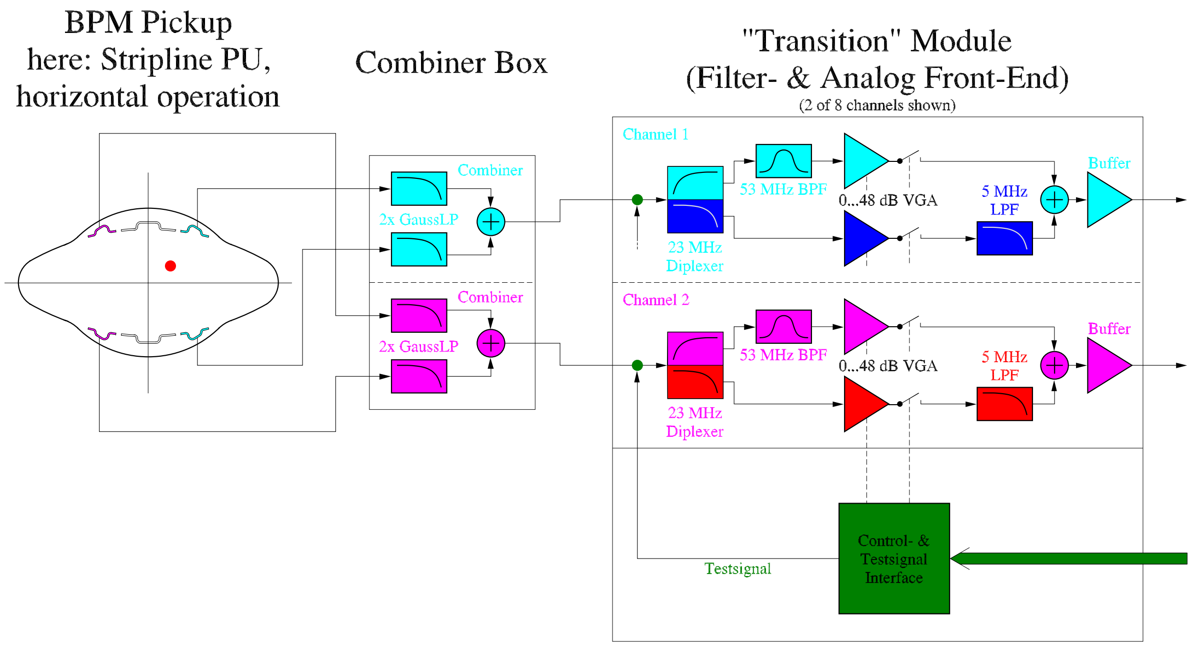


Figure 2: MI BPM analog hardware.

Fig. 1 gives an overview of the MI BPM hardware (see also [1]). The *Transitionboard* (or *Transitionmodule*) interfaces the MI BPM pickup signals to the *Echotek* digitizer (digital receiver) module. It basically consists out of 2 independent, selective gain stages per channel; one for 53 MHz, one for 2.5 MHz (see Fig. 2). These gain stages should boost the signals levels received from the stripline BPM pickup (or extrawide aperture BPM) to an adequate level, i. e. 10...70 % full-scale range ($\equiv$ 0.1...0.7 $V_{pp}$) of the *Echotek* digitizer. The gain of a pair of stages can be controlled in a range 0...60 dB, 0...48 dB continuously plus 12 dB switched. The 6U high Transitionboard, currently in design, keeps a total of 8 channels, thus meets the input channel number of the corresponding *Echotek* digitizer module.

# MI Beam Conditions and BPM Signal Levels

[2] discusses in detail the requirements for the MI BPM System Upgrade. Concerning the Transitionboard, the beam conditions described in Tables 2...6 specify (indirect) most of the requirements for the Transitionboard. From the Tables, we extract the dynamic range due to beam intensity and bunch length variations for 2.5 MHz and 53 Mhz spaced bunches. Measurements where taken at the MI-30 test setup ([3], [4]), compared with beam/pickup simulations ([5], [6]) and the signal levels are then extrapolated applying the most extreme beam conditions of those tables.

| | | signal level | beam conditions ($t_B$: 95 % bunch length) |
|---|---|---|---|
| 2.5 MHz | min. | 0.62 $mV_{pp}$ | single coalesced $\bar{p}$-bunch, $5\times10^9$ $\bar{p}$/bunch, $t_B \approx 200$ ns |
| | max. | 88 $mV_{pp}$ | single coalesced $\bar{p}$-bunch, $150\times10^9$ $\bar{p}$/bunch, $t_B \approx 150$ ns |
| 53 MHz | min. | 3 $mV_{pp}$ | single coalesced $\bar{p}$-bunch, $10\times10^9$ $\bar{p}$/bunch, $t_B \approx 23$ ns |
| | max. | 6.6 $V_{pp}$ | uncoalesced p-bunch batch (> 20), $200\times10^9$ $\bar{p}$/bunch, $t_B \approx 1.5$ ns |

Table 1: Mapping of expected MI beam conditions and BPM signal levels

Table 1 gives an idea of the expected signal level ranges. These levels include the influence of the *Combinerbox* (summing of signals and internal losses) and the shape effects of passive filter-networks:

- a 10 MHz BW low-pass filter for the 2.5 MHz signals
- a 53 MHz CF, 5 MHz BW band-pass filter for the 53 MHz signals

Also included are the losses of 300...1300 ft long RG-8 coaxial cables.

| | max. level – min. level | dyn. range |
|---|---|---|
| 2.5 MHz | -17.3 dBm – -60.2 dBm | 43.1 dB |
| 53 MHz | +20.4 dBm – -46.5 dBm | 66.9 dB |

Table 2: Dynamic range of the MI BPM signals

Table 2 lists the signal levels , now in dBm, and the corresponding dynamic ranges.

## Requirements for the MI BPM Transitionboard

- Main task of the Transitionboard is to amplify/attenuate the various signal levels (Table 2) to be adapted to the 1 $V_{pp}$ ($\equiv$ +4 dBm) full-scale range of the single-ended analog inputs of the *Echotek* digitizer module. High 53 MHz levels should not cause saturation effects in the gain stages of the Transitionboard. Furthermore the inputs of the *Echotek* digitizer should be protected from too high signal levels, i. e. $> 1.8$ $V_{pp}$.
- The noise floor of the Transitionboard has to be sufficiently low, in order to achieve the required 0.5/0.1 mm (2.5/53 MHz, $3\sigma$) position resolution for low intensity beams.
- The bandwidth of the Transitionboard has to be large enough, to time-resolve individual batches of 1...84 bunches, spaced by 1/53 MHz. This booster batch time $t_{rev}/7 \approx 1.585$ $\mu$s requires a bandwidth $> 220$ kHz.
- The gain- and linearity mismatch of a pair of channels has to accomplish the MI BPM system requirement, see [2]. A mismatch $< 0.2$ dB is tolerable and within those specifications.
- The Transitionboard has to supply 2.5/53 MHz test signals for a basic functional test of the BPM system in the absence of beam.

## Description of the MI BPM Transitionboard

Fig. 2 shows a simplified block diagram with 2-of-8 channels of the Transitionboard. The concept of selective 2.5 and 53 MHz gain stages was “stolen” from the development of the *RT BPM Transitionboard* [7], which also served a backup solution.

While keeping the same 53 MHz band-pass filters, we changed the design toward an integrated VGA and removed all mechanical relays and switches from the signal path. Now a diplexer with 23 MHz cross-over frequency spits the signals at the input, and path them to the *Analog Devices* AD8332 low-noise 2-channel variable gain amplifier (VGA). Fig. 3 shows the functional block diagram of the AD8332. From the data sheet (see also: http://www.analog.com) the main characteristics are given:

- Low-noise preamplifier: $0.74\ \mathrm{nV}/\sqrt{\mathrm{Hz}}$, $2{,}5\ \mathrm{pA}/\sqrt{\mathrm{Hz}}$
- 120 MHz bandwidth (3 dB)
- Two 48 dB gain ranges in 6 dB steps:

  **LO** -4.5 dB...+43.5 dB

  **HI** +7.5 dB...+55.5 dB
- Typical channel-to-channel gain error (mismatch): $\pm$ 0.1 dB

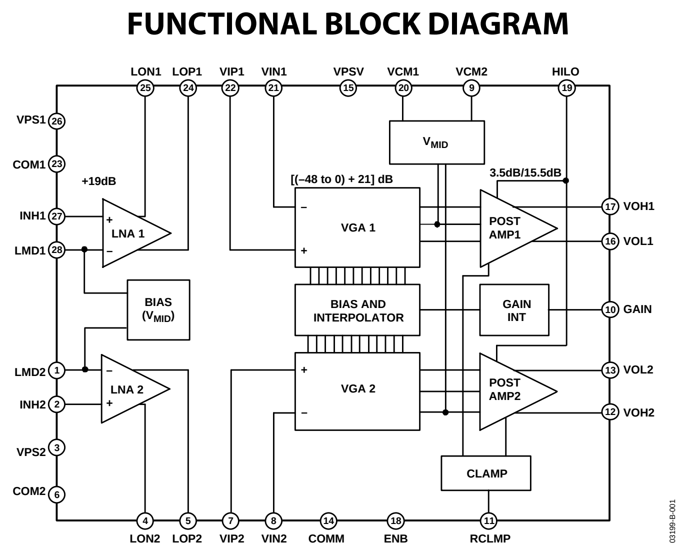


Figure 3: Functional block diagram of the *Analog Devices* AD8332 variable gain amplifier (VGA).

Differential receiver OpAms (AD8129/AD8130) are used to convert the AD8332 differential output signals to single-ended, give more gain and combine the signals from the 2.5 MHz and the 53 MHz gain path. The $\overline{\mathrm{PD}}$-pin (power-down) of the OpAmp is used to on/off-switch the frequency selective gain stages. The single-ended output of the Trasitionboard is driven by an OPA692 buffer.

All elements are controlled from a FPGA, which also serves the test signals, to remotely control all functions of the Transitionboard.

Preliminary measurements of a 2-channel prototype Transitionboard without remote control are summarized in [8].

# References

[1] M. Wendt, “MI BPM review: BPM HARDWARE OVERVIEW”, Beams-doc-1909-v6

[2] D. Capista and A. Marchionni, “Requirements for the Main Injector BPM Upgrade” (draft), Beams-doc-1786-v2

[3] P. Prieto, et. al., “Proton and PBar Beam Measurements in the Main Injector”, Beams-doc-1780-v1

[4] R. Webber, et. al., “Anti-Proton Beam Position Measurements with Prototype Equipments at MI-30”, Beams-doc-1958-v1

[5] M. Wendt, “MI Stripline BPM: Analysis of Position Characteristic and Output Signal”, Beams-doc-1803-v1

[6] M. Wendt, “MI Electrostatic BPM’s with Extra Wide Aperture: Analysis of Position Characteristic and Linearity”, Beams-doc-1824-v1

[7] N. Eddy, “BPM Filter Module for Transfer Lines”, Beams-doc-1849-v1

[8] M. Wendt, “Measurements on the MI BPM Transitionboard” (draft), Beams-doc-1968-v2